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## **SECTION II: CHAPTER 3**

### **VENTILATION INVESTIGATION**

#### **A. INTRODUCTION**

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Ventilation can be categorized into industrial and non-industrial systems. Industrial ventilation generally involves the use of local mechanical supply and exhaust ventilation to control employee exposures to harmful substances.. Heating, ventilating, and air-conditioning (HVAC) systems are generally referred to as non-industrial or comfort ventilation equipment and are usually installed to control temperature, humidity, and odors.

Ventilation is often found to be deficient in:

- \* confined spaces,
- \* process areas with tanks having poorly designed local ventilation,
- \* facilities with inadequately maintained ventilation equipment,
- \* facilities operated to maximize energy conservation,
- \* windowless areas, and
- \* areas with high occupant densities.

There are five basic types of ventilation systems:

- \* dilution and removal by general exhaust,
- \* local exhaust (see Figure II:3-1),
- \* makeup, supply or replacement air,
- \* HVAC, and
- \* recirculation systems.

Ventilation systems generally involve a combination of these types of systems. For example, a large local exhaust system may also serve as a dilution system, and the HVAC system may serve as a makeup or supply air system. Appendix II:3-1 is provided as a primer for ventilation and Appendix II:3-2 provides a glossary of commonly used ventilation terms.

## **B. HEALTH EFFECTS**

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Inadequate or improper ventilation is the cause of about half of all indoor air quality (IAQ) problems in nonindustrial workplaces (see Section II, Chapter 2, Indoor Air Quality). This section of the Technical Manual addresses ventilation in commercial buildings and industrial facilities.

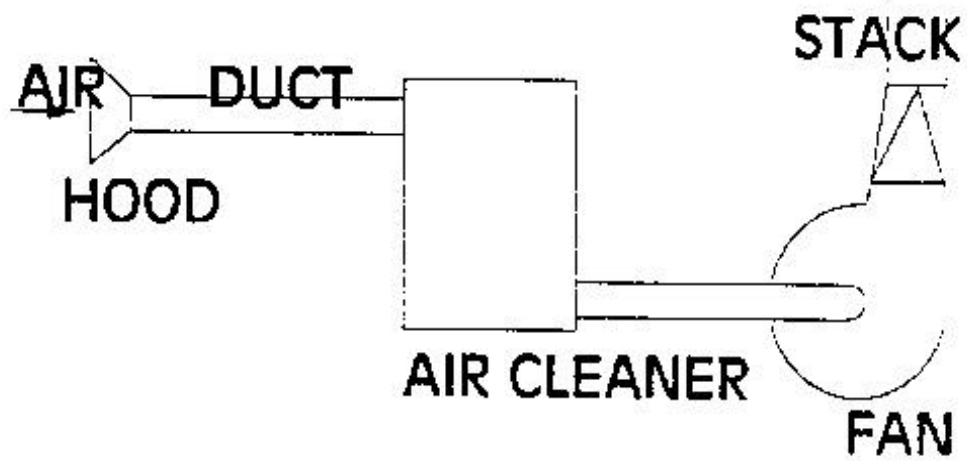
Indoor air contaminants include but are not limited to particulates, pollen, microbial agents, and organic toxins. These can be transported by the ventilation system or originate in the following parts of the ventilation system:

- \* wet filters,
- \* wet insulation,
- \* wet undercoil pans,
- \* cooling towers, and
- \* evaporative humidifiers.

People exposed to these agents may develop signs and symptoms related to "humidifier fever," "humidifier lung," or "air conditioner lung." In some cases, indoor air quality contaminants cause clinically identifiable conditions such as occupational asthma, reversible airway disease, and hypersensitivity pneumonitis.

Volatile organic and reactive chemicals, e.g., formaldehyde, often contribute to indoor air contamination. The facility's ventilation system may transport reactive chemicals from a source area to other parts of the building. Tobacco smoke contains a number of organic and reactive chemicals and is often carried this way. In some instances the contaminant source may be the outside air. Outside air for ventilation or makeup air for exhaust systems may bring contaminants into the workplace, e.g., vehicle exhaust, fugitive emissions from a neighboring smelter.

See Section II, Chapter 2, Indoor Air Quality, for a discussion of common indoor-air contaminants and their biological effects.



**Figure II:3-1.** Components of a local exhaust system.

## **C. T8-CCR AND CONSENSUS STANDARDS**

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Appendix II:3-3 is a compilation of T8-CCR and industry consensus standards. Several private organizations have developed and recommend ventilation standards. They include:

- \* Air Movement and Control Association (AMCA), a trade association that has developed standards and testing procedures for fans.
- \* American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), a society of heating and air conditioning engineers that has produced, through consensus, a number of standards related to indoor air quality, filter performance and testing, and HVAC systems.
- \* American National Standards Institute (ANSI) has produced several important standards on ventilation, including ventilation for paintspray booths, grinding exhaust hoods, and open-surface tank exhausts
- \* Sheet Metal and Air Conditioning Contractors National Association (SMACNA) is an association representing sheet metal contractors and suppliers which has set standards for ducts and duct installation.
- \* National Fire Protection Association (NFPA) has produced a number of recommendations which become requirements when adopted by local fire agencies, e.g., NFPA 45 which lists a number of ventilation requirements for laboratory fume hood use.
- \* American Conference of Governmental Industrial Hygienists (ACGIH) has published widely used guidelines for industrial ventilation.

### **T8-CCR REQUIREMENTS**

Ventilation requirements are included in T8-CCR Regulations which cover general indoor air quality ventilation as well as job-or task-specific industrial ventilation to prevent harmful exposures to employees. The most frequently used Sections related to these issues are T8-CCR 5142 for HVAC systems and T8-CCR 5141 related to feasible engineering controls which includes ventilation. An example list of T8-CCR regulations related to ventilation are shown in Appendix II:3-3.

## **D. INVESTIGATION GUIDELINES**

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Workplace investigations of ventilation systems may be initiated by worker complaints of possible overexposure to airborne biological and chemical contaminants, possible risk of fire or explosion from flammable gas or vapor levels at or near the lower explosive limit (LEL), or non-specific indoor air quality complaints. The Guidelines specified in the DOSH Policy and Procedure Manual for Tuberculosis shall be followed when conducting Tuberculosis evaluations.

The second phase of the investigation involves an examination of the ventilation system's physical and operating characteristics. Any ventilation deficiency must be verified by measurement. Common faulty ventilation conditions and their probable causes are listed in Table II:3-1. Specific points to consider during any investigation of a ventilation system include emission source, air behavior, and employee involvement. Points that should be included in a review of operational efficacy are shown in Table II:3-2. Appendix II:3-4 contains information on points to be checked in a troublesome exhaust system.

Basic testing equipment could includes:

- \* Smoke tubes;
- \* Velometers, anemometers:
  - Swinging vane anemometer,
  - Thermal or hot-wire anemometer,
  - Balometer
- \* Pressure-sensing devices:
  - U-tube or electronic manometers,
  - Pitot tube,
  - Thermal (thermal and swinging vane instruments measure static pressure indirectly),
  - Aneroid ("bellows") gauges;
- \* Noise-monitoring equipment;
- \* Measuring tapes;
- \* Other: rags, flashlight, masking tape, felt marker, mirror, tachometer;
- \* Combustible gas meter, CO, hydrogen sulfide and/or oxygen meter;
- \* Colorimetric detector tubes for CO, CO<sub>2</sub>, formaldehyde, etc.

Characteristics of the ventilation system that must be documented include equipment operability, physical measurements of the systems, and use practices.

### **EQUIPMENT OPERABILITY**

Before taking velocity or pressure measurements, note and record the operating status of the equipment.

- \* Are filters loaded or clean?

- \* Is the return air plenum free of standing water, algae?
- \* Are the fresh air intakes located near a contamination source, e.g. pigeon roost, exhausts?
- \* Are variable-flow devices like dampers, variable-frequency drives, or inlet vanes in use?
- \* Are dampers open or closed?
- \* Are make-up units operating?
- \* When does the system operate?
- \* Are system blueprints available?

**TABLE II:3-1. COMMON VENTILATION CONDITIONS AND CAUSES**

Condition	Possible cause(s)
Improper use of system	Hood interferes with work.
Nonuse of system	Poor hood control of contaminants
Employees alter system	.
Excessive employee exposures although flow volumes and capture velocities are at design levels	Employee work practices need improvement. Ventilation system interferes with work or worker productivity, leading workers to bypass the system. Employee training is not adequate. Design of system is poor
Constant plugging of duct	. Plugged ducts occur when transport velocity is inadequate or when vapor condenses in the duct, wets particles, and causes a build-up of materials. These problems are caused by poor design, open access doors close to the fan, fan problems, or other problems.
Low capture velocities or excessive fugitive emissions	The cause of these conditions is usually reduced flow rate, unless the process itself has changed. Reduced flow rate occurs in the following situations: <ul style="list-style-type: none"> <li>- plugged or dented ducts</li> <li>- slipping fan belts</li> <li>- open access doors</li> <li>- holes in ducts, elbows</li> <li>- closed blast gate to branch</li> <li>- opened blast gates to other branches</li> <li>- corroded and stuck blast gates</li> <li>- worn out fan blades</li> <li>- branches added to system since initial installation</li> <li>- hoods added to system since initial installation</li> <li>- clogged air cleaner.</li> <li>- fan turning in reverse direction</li> </ul> <p>(NOTE: Reverse fan direction can occur when lead wires are reversed and cause the motor and fan to turn backwards. Centrifugal fans turning backwards may deliver up to only 50% of rated capacity.)</p>

## MEASUREMENTS

### Duct Area

In order to evaluate air flow in a ventilation system, it is often necessary to determine the interior area of a duct. The shape of the ducts are usually square, rectangular or round. The interior area of square, rectangular or round uninsulated thin sheet metal ducts can be simply estimated by placing a measuring tape on the exterior of the duct. Ducts with interior or exterior insulation and/or double wall ducts require a direct measurement of the interior wall unless design or as built specifications are available.

For rectangular and square ducts, measure the opening height and multiply the value times the opening base dimension to obtain the area.

Example: Square or rectangular ducts

Exterior dimension of the duct opening measured 6 inches by 12 inches.

Area of rectangular or square =  $H \times B$ ; where  $H$  = height and  $B$  = base

Area = 6 inches x 12 inches = 72 square inches.

To change to square feet, divide the area by 144 square inches, i.e.,

72 square inches  $\div$  144 square inches/square foot = 0.5 square feet

144 square inches/square foot (Conversion Factor)

Example: Round ducts

The exterior circumference of a round duct was measured at 37.7 inches.

To determine the area of a circular duct, the first step is to determine the diameter (D).

Diameter (D) = Circumference (C)  $\div$  3.142; where 3.142 is the value of  $\pi$ . Therefore,

$D = 37.7 \text{ inches} \div 3.142 = 11.9$  or 12 inches diameter duct. (Equation:  $D = C \div \pi$ )

The second step is to determine the radius (R) of the circle. Radius (R) = Diameter (D)  $\div$  2.

Therefore  $R = 12 \text{ inches} \div 2 = 6$  inches radius. (Equation:  $R = D \div 2$ )

The third step is to determine the area (A) of the circle. Area (A) = 3.142 x Radius (R) squared.

Therefore,  $A = 3.142 \times (6 \text{ inches})^2 = 113$  square inches. 113 square inches  $\div$  144 square inches/square foot = 0.8 square feet. (Equation:  $A = \pi R^2$ )

Hood and duct dimensions can be estimated from plans, drawings, and specifications. Measurements can be made with measuring tape. If a duct is constructed of 2 ½ or 4foot sections, the sections can be counted and elbows and tees should be included in the length.

## Air Velocity

Air velocity (V) is a measure of distance (D) per unit time (T) or  $V = D/T$ .

Air velocity measurements can be obtained to determine total air flow or air exchange in a ventilation system and to determine the ability of the system to capture contaminate. Total air flow or volume is important in evaluating an HVAC as well as determining the efficiency of local industrial exhaust systems.

Hood-face velocities outside the hood or at the hood face can be estimated with Velometers, smoke tubes, thermoanemometers, and swinging-vane anemometers. Air supply and exhaust for HVAC systems can be evaluated using the same equipment and a Balometer.

The minimum velocity that can be read by an anemometer is 50 feet per minute (fpm). The meter should always be read in the upright position, and only the tubing supplied with the equipment should be used.

Anemometers often cannot be used if the duct contains dust or mist because air must actually pass through the instrument for it to work.

Thermoanemometers, known as hot wire anemometers, with some units equipped with data logging capabilities, must not be used to evaluate spray booths or inside duct work because the heated wire filament may be contaminated with dust and pigments and may pose a fire hazard if used in air streams containing aerosols.

A velometer, i.e., an instrument which provide air volume measurements directly, is equipped with hood that is generally used to evaluate HVAC system by placing the hood opening over supply and exhaust ducts. The velometer can be used to evaluate ceiling ducts and wall mounted ducts, however, the meter must not be used in a position where the needle actuates in a vertical position because a positive deflection will be shown due to gravity effects.

Hood-face velocity measurement involves the following steps:

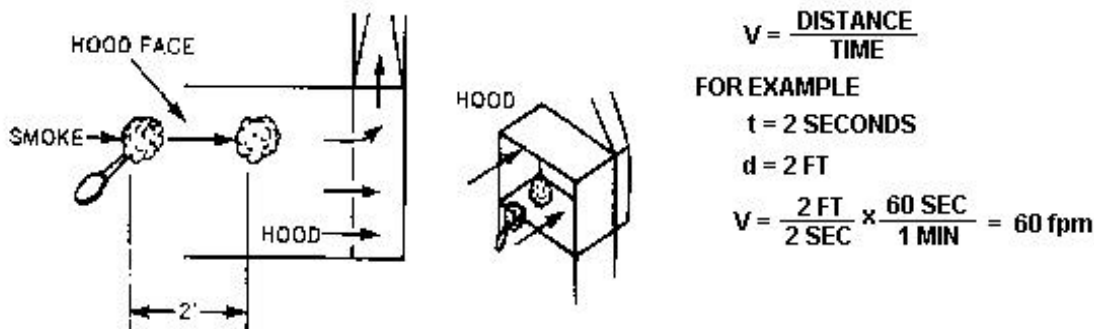
- \* mark off imaginary areas,
- \* measure velocity at center of each area, and
- \* average all measured velocities.

A technique that can be used to mark off areas to conduct velocity measurements, is to use masking tape applied around the opening and marked at various intervals using a felt tipped marker to simulate a hypothetical grid pattern across the face of the hood, door, vent, duct, etc.

## Smoke Testing

Smoke is useful for determining which way the air is moving, e.g. in or out of a room, HVAC supply air or exhaust, and for measuring face velocity (see Figure II:3-2) because it is visible.

Nothing convinces management and employees more quickly that the ventilation is not functioning properly than to show smoke drifting away from the hood, escaping the hood, migrating to a normal work area from a contagious disease isolation room or traveling into the worker's breathing zone.



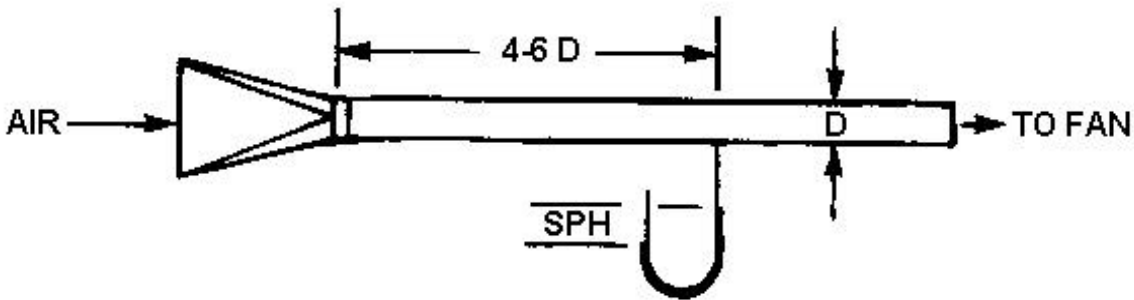
**Figure II:3-2. Use of smoke to demonstrate air flow**

Breathing “irritant smoke” can cause irritation of the respiratory track and of the eye and can become deleterious to contact with some metal surfaces because of its corrosivity. Care should be taken to avoid exposure. Smoke can be used to provide a rough estimate of face velocity. Velocity measurements can be obtained by creating a quick burst of smoke. Time the smoke plume's travel over a two-foot distance. Calculate the velocity in feet per minute. For example, if the smoke traveled a distance (D) of two (2) feet during a period of time (T) of two (2) seconds the velocity is  $V = D/T = 2 \text{ feet} / 2 \text{ second}$  or 1 ft/second. Typically, the resultant 1 ft/second would be converted to feet per minute (fpm) e.g.  $1 \text{ ft/second} = 60 \text{ fpm}$ .

## **OTHER MEASUREMENTS**

Some of the ventilation measuring methods discussed below require that holes be made in the ventilation duct work. DOSH personnel are not to perform these evaluations without consulting with the Senior Industrial Hygienist.

Hood static pressures (SPH) should be measured about 4-6 duct diameters downstream in a straight section of the hood take-off duct. The measurement can be made with a pitot tube or by a static pressure tap into the duct sheet metal (see Figure II:3-3).



**Figure II:3-3. Use of static pressure tap into duct to measure hood static pressure.**

Pressure gauges come in a number of varieties, the simplest being the U-tube manometer. Inclined manometers offer greater accuracy and greater sensitivity at low pressures than U-tube manometers. However, manometers rarely can be used for velocities less than 800 fpm, i.e., velocity pressures less than 0.05" w.g. Aneroid-type manometers use a calibrated bellows to measure pressures. They are easy to read and portable but require regular calibration and maintenance.

Duct velocity measurements may be made directly (with velometers and anemometers) or indirectly (with manometers and pitot tubes) using duct velocity pressure. Air flow in industrial ventilation ducts is almost always turbulent, with a small, nonmoving boundary layer at the surface of the duct. Because velocity varies with distance from the edge of the duct, a single measurement may not be sufficient. However, if the measurement is taken in a straight length of round duct, 4-6 diameters downstream and 2-3 diameters upstream from obstructions or directional changes, then the average velocity can be estimated at 90% of the centerline velocity. The average velocity pressure is about 81% of centerline velocity pressure.

A more accurate method is the traverse method, which involves taking six or ten measurements on each of two or three passes across the duct, 90 degrees or 60 degrees opposed. Measurements are made in the center of concentric circles of equal area.

Density corrections, e.g., temperature, for instrument use should be made in accordance with the manufacturer's instrument instruction manual and calculation/correction formulas.

Air cleaner and fan condition measurements can be made with a pitot tube and manometer.

## **GOOD PRACTICES**

Hood placement must be close to the emission source to provide effective capture of contaminants. The maximum distance from the emission source should not exceed 1.5 duct diameters.

The approximate relationship of capture velocity ( $V_c$ ) to duct velocity ( $V_d$ ) for a simple plain or narrow flanged hood is illustrated in Figure II:3-4.

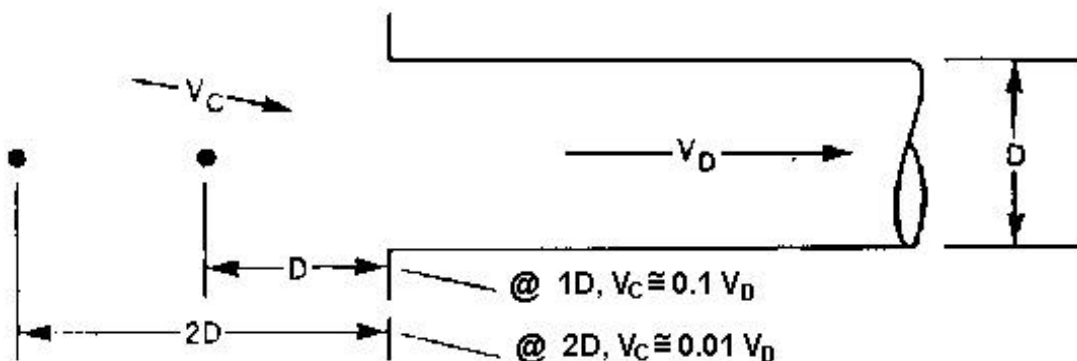


Figure II:3-4. Relationship of capture velocity ( $V_c$ ) to duct velocity ( $V_d$ ).

For example, if an emission source is one duct diameter in front of the hood and the duct velocity ( $V_d$ ) = 3,000 feet per minute (fpm), then the expected capture velocity ( $V_c$ ) would be about 10 % of the  $V_d$  or 300 fpm. At two duct diameters from the hood opening, capture velocity decreases by a factor of 10, to  $V_c$  of 30 fpm.

Figure II:3-5 shows a rule of thumb that can be used with simple capture hoods. If the duct diameter ( $D$ ) is 6 inches, then the maximum distance of the emission source from the hood should not exceed 9 in. Similarly, the minimum capture velocity should not be less than 50 fpm.

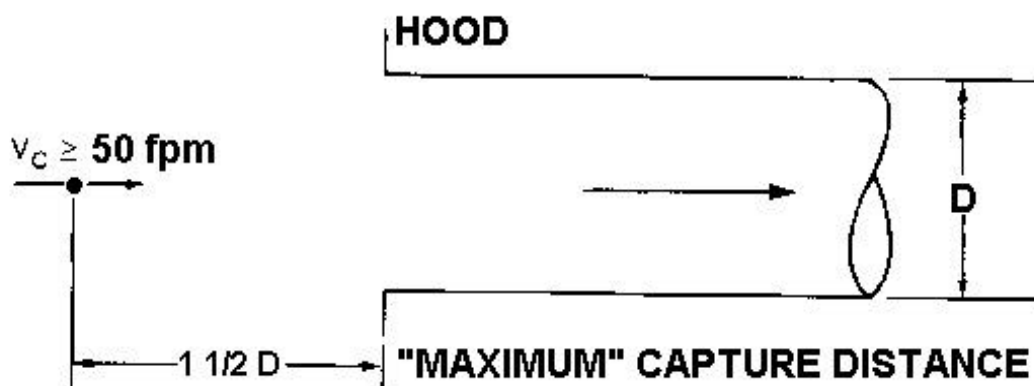
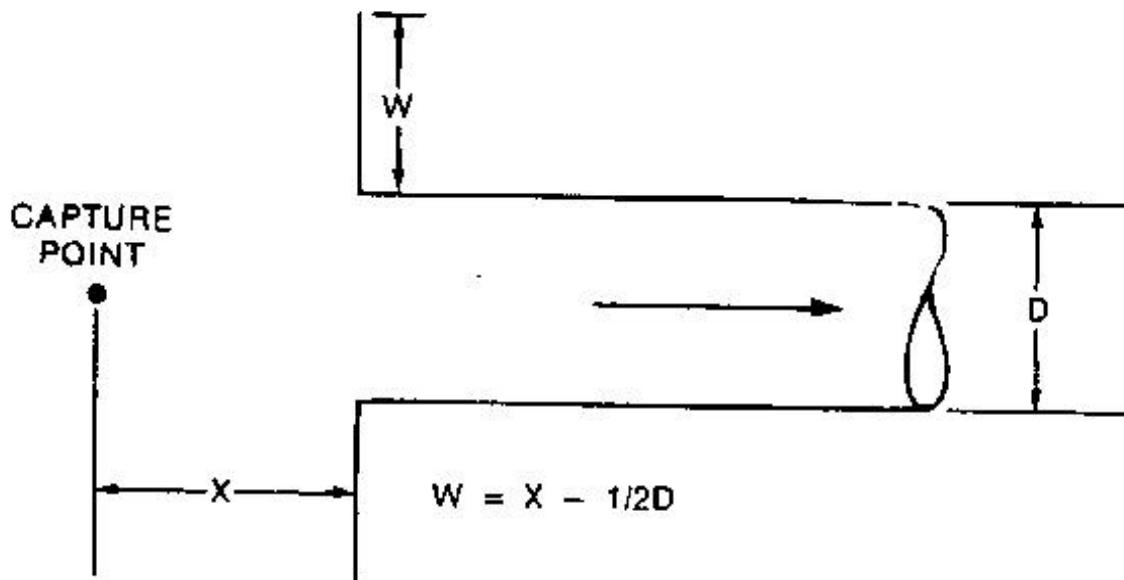


Figure II:3-5. Rule of Thumb for simple capture hoods: Maximum capture distance should not be more than 1.5 times the duct diameter.

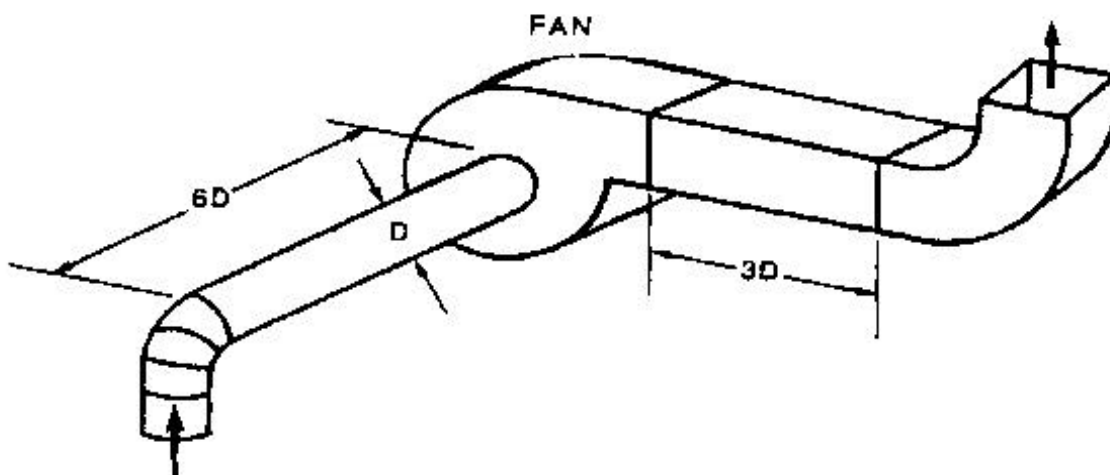
Figure II:3-6 provides a guide for determining an effective flange width.



**Figure II:3-6. Effective flange width ( $W$ ).**

System effect loss, which occurs at the fan, can be avoided if the necessary ductwork is in place.

Use of the six-and-three rule ensures better design by providing for a minimum loss at six diameters of straight duct at the fan inlet and a minimum loss at three diameters of straight duct at the fan outlet (Figure II:3-7).

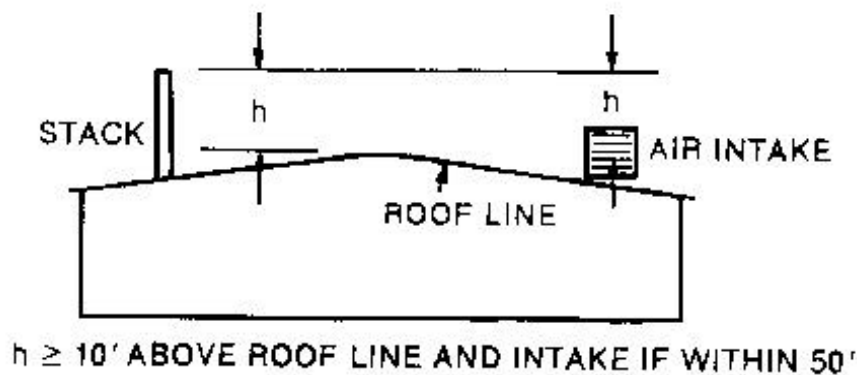


**Figure II:3-7. An illustration of the six-and-three rule.**

System effect loss is significant if any elbows are connected to the fan at inlet or outlet.

For each 2 ½ diameters of straight duct between the fan inlet and any elbow, CFM loss will be 20%.

Stack height should be 10 ft higher than any roof line or air intake located within 50 ft of the stack (Figure II:3-8). For example, a stack placed 30 ft away from an air intake should be at least 10 ft higher than the center of the intake.



**Figure II:3-8. Minimum stack height in relation to immediate roof line or center of any air intake on the same roof.**

## Plan Review

Ventilation system drawings and specifications usually follow standard forms and symbols, e.g., as described in the Uniform Construction Index (UCI). Plan sections include electrical, plumbing, structural, or mechanical drawings (UCI, Section 15). The drawings come in several views: plan (top), elevation (side and front), isometric, or section.

Elevations, or side and front views, give the most detail. An isometric drawing is one that illustrates the system in three dimensions.

A sectional drawing provides duct or component detail by showing a cross-section of the component.

It should be determined whether the drawings provided for review are the design plans or as-built plans. The installation may differ from the original design and/or modifications may have been made to the ventilation system since the original construction. Drawings are usually drawn to scale. The dimensions and lengths on the drawing should be checked with a ruler or a scale to be sure that this is the case. For example, 1/8 inch on the sheet may represent one foot on the

ground.

Good practices to follow when reviewing plans and specifications are listed in Table II:3-3.

**TABLE II:3-3. GOOD PRACTICES FOR REVIEWING PLANS AND SPECIFICATIONS**

- |   |
|---|
| <ul style="list-style-type: none"><li>* Investigate the background and objectives of the project.</li><li>* Understand the scope of the project. What is to be included and why?</li><li>* Look for conciseness and precision. Mark ambiguous phrases, "legalese," and repetition.</li><li>* Do the specifications spell out exactly what is wanted? What is expected?</li><li>* Do plans and specifications adhere to appropriate codes, standards, requirements, policies, and do they recommend good practice as established by the industry?</li><li>* Will the designer be able to design, or the contractor to build, the system from the plans and specifications?</li><li>* Will the project meet OSHA requirements if it is built as proposed?</li></ul> |
|---|

## **E. PREVENTION AND CONTROL**

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A well-designed and installed system with a good continuing preventive maintenance program are key elements in the prevention and control of ventilation system problems.

### **ELEMENTS OF A GOOD MAINTENANCE PROGRAM**

To have a good maintenance program the employer must maintain records. The employer should have established a safe place to file drawings, specifications, fan curves, operating instructions, and other papers generated during design, construction, and testing.

The employer should have established a program of periodic testing and inspection. The minimum types and frequencies of inspections are required by T8-CCR but will also depend on the operation of the system and other factors. Although not necessarily required specifically by T8-CCR, determine if the following is performed:

- \* Daily: Visual inspection of hoods, ductwork, access and clean-out doors, blast gate positions, hood static pressure, pressure drop across air cleaner, and verbal contact with users. ("How is the system performing today?")
- \* Weekly: Air cleaner capacity, fan housing, pulley belts.
- \* Monthly: Air cleaner components.
- \* Annual testing
- \* Records of all maintenance, repairs and testing results.

A quick way to check for settled material in a duct is to take a broomstick and tap the underside of all horizontal ducts. If the tapping produces a "clean" sheet metal sound, the duct is clear. If the tapping produces heavy, thudding sounds and no sheet metal vibration, liquids or settled dust may be in the duct.

The employer should have established a preventive maintenance program. Certain elements of any ventilation system should be checked on a regular schedule and replaced if found to be defective.

Determine if the employer has provided worker training. Workers need to be trained in the purpose and functions of the ventilation system. For example, they need to know how to work safely and how best to utilize the ventilation system.

Exhaust hoods do little good if the welder does not know that the hood must be positioned close to the work.

Check to determine if the employer is keeping written records. Maintain written documentation not only of original installations but also of all modifications as well as problems and their resolution.

## **MICRO-ORGANISMS**

If microbial agents are suspected of causing harmful exposures, check for stagnant water in the ventilation system. The presence of mold or slime is a possible sign of trouble. Table II:3-4 lists preventive measures for controlling microbial problems in ventilation systems.

It may be necessary, especially related to HVAC systems, to take airborne samples to substantiate the presence of microbes at the worksite. Do not take microbial samples unless the issue has been discussed with the Senior Industrial Hygienist.

## **ORGANIC OR REACTIVE CHEMICALS**

If an organic or reactive chemical e.g., formaldehyde, is believed to be the primary agent in an IAQ problem, potential controls to consider include additional dilution ventilation, removal or isolation of the offending material, and the transfer of sensitized employees.

## **TOBACCO SMOKE**

Smoking in places of employment is prohibited by California Labor Code (LC) Section 6404 and 6404.5. Primary enforcement is assigned to local jurisdictions. DOSH is not required to respond to any complaint regarding the smoking of tobacco products in an enclosed space unless the employer has been found guilty of a third violation within the previous year.

In those places of employment exempt from the LC, the employers smoking policies should include provisions for dedicated smoking areas. Dedicated smoking areas should be configured so that migration of smoke into nonsmoking areas will not occur. Such areas should:

- \* have floor-to-ceiling walls of tight construction;
- \* be under negative pressure relative to adjacent areas;
- \* be exhausted outside the building and not recirculated.

For more information on investigation of complaints, compliance personnel should consult the NIOSH Guidance for Indoor Air Quality Investigation and the EPA guide, Building Air Quality (1991).

**TABLE II:3-4.**

**PREVENTIVE MEASURES FOR  
REDUCING MICROBIAL PROBLEMS IN BUILDINGS**

- |  |
|--|
| <ul style="list-style-type: none"><li>* Prevent buildup of moisture in occupied spaces, e.g., relative humidity of 60% or less.</li><li>* Prevent moisture collection in HVAC components.</li><li>* Remove stagnant water and slime from mechanical equipment.</li><li>* Use steam for humidifying.</li><li>* Avoid use of water sprays in HVAC systems.</li><li>* Use filters with a 50-70% collection efficiency rating.</li><li>* Find and discard microbe-damaged furnishings and equipment.</li><li>* Provide regular preventive maintenance.</li></ul> |
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**F. ENFORCEMENT POLICY**

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Ventilation violations shall be cited in accordance with the provisions of DOSH Policy and Procedure (DOSH-P&P) C-1B, Appendix F. Ventilation related violations concerning IAQ and Tuberculosis will be evaluated and cited as specified in DOSH-P&P C-47, Interim Tuberculosis Control Enforcement Guidelines and DOSH-P&P C-48, Indoor Air Quality.

## **G. BIBLIOGRAPHY**

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American Conference of Governmental Industrial Hygienists (ACGIH). 1988. Industrial Ventilation, a Manual of Recommended Practice. 20th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Air Movement and Control Association (AMCA). 1988. AMCA Publication One. Arlington Heights, IL: Air Movement and Control Association.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Handbooks and Standards. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). SMACNA Publications. Arlington, VA: Sheet Metal and Air Conditioning Contractors National Association.

American National Standards Institute (ANSI) Standards:

Z9.1 - Open Surface Tanks Operation

Z9.2 - Fundamentals Covering the Design and Operation of Local Exhaust Systems

Z9.3 - Design, Construction, and Ventilation of Spray Finishing Operations

Z9.4 - Ventilation and Safe Practice of Abrasive Blasting Operations

Z9.5 - Laboratory Ventilation. Fairfax, VA: American Industrial Hygiene Association.

Burgess, W. A. et al. 1989. Ventilation and Control of the Work Environment. New York: Wiley Interscience.

Burton, D. J. 1989. Industrial Ventilation Workbook. Salt Lake City, UT: IVE, Inc.

Burton, D. J. 1990. Indoor Air Quality Workbook. Salt Lake City, UT: IVE, Inc.

Jorgensen, R. et al. 1983. Fan Engineering. 8th ed. Buffalo, NY: Buffalo Forge Co.

Homeon, W. C. L. 1963. Plant and Process Ventilation. New York: Industrial Press.

National Institute for Occupational Safety and Health (NIOSH). 1987. Guidance for Indoor Air Quality Investigations. Cincinnati: NIOSH.

OSHA Field Operations Manual. 1992. OSHA Instruction CPL 2.45B. Washington, D.C.: U.S. Government Printing Office.

U.S. Environmental Protection Agency (EPA). 1991. Building Air Quality.

## APPENDIX II:3-1. VENTILATION PRIMER

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### SELECTION

Before an appropriate ventilation system can be selected, the employer should study emission sources, worker behavior, and air movement in the area. In some cases the employer may wish to seek the services of an experienced professional ventilation engineer to assist in the data gathering. Table II:3-5 shows factors to consider when selecting a ventilation system. Combinations of controls are often employed for HVAC purposes.

**TABLE II:3-5.**  
**SELECTION CRITERIA FOR GENERAL AND LOCAL EXHAUST SYSTEMS**

General exhaust ventilation, known as dilution ventilation, is appropriate when:

- \* emission sources contain materials of relatively low hazard.
- \* degree of hazard is related to toxicity, dose rate, and individual susceptibility.
- \* emission sources are primarily vapors or gases,
- \* emission sources are small, respirable-size aerosols and therefore, not likely to settle;
- \* emissions occur uniformly;
- \* emissions are widely dispersed;
- \* moderate climatic conditions prevail;
- \* heat is to be removed from the space by flushing it with outside air;
- \* concentrations of vapors are to be reduced in an enclosure; and
- \* portable or mobile emission sources are to be controlled.

Local exhaust ventilating is appropriate when:

- \* emission sources contain materials of relatively high hazard;
- \* emitted materials are primarily larger-diameter particulates which are likely to settle
- \* emissions vary over time ;
- \* emission sources consist of point sources;
- \* employees work in the immediate vicinity of the emission source;
- \* the plant is located in a severe climate; and
- \* minimizing air turnover is necessary.

## GENERAL EXHAUST (DILUTION) VENTILATION SYSTEMS

General exhaust ventilation is different from local exhaust ventilation because instead of capturing emissions at their source and removing them from the air, general exhaust ventilation allows the contaminant to be emitted into the workplace air and then dilutes the concentration of the contaminant to an acceptable level, e.g., to the PEL or below. Dilution systems are often used to control evaporated liquids.

To determine the correct volume flow rate for dilution ( $Q_d$ ), it is necessary to estimate the evaporation rate of the contaminant ( $q_d$ ):

$$q_d = \frac{387 \times \text{lbs}}{\text{MW} \times \text{min} \times d}$$

Where

- $q_d$  = evaporation rate in acfm
- 387 = volume in cubic feet formed by the evaporation of one lb-mole of a substance, e.g., a solvent
- MW = molecular weight of emitted material
- lbs = lbs of material evaporated
- min = time of evaporation
- d = density correction factor

The appropriate dilution volume flow rate for toxics is:

$$Q_d = (q_d \times K_m \times 10^6) / C_a$$

Where

- $Q_d$  = volume flow rate of air, in acfm
- $q_d$  = evaporation rate, in acfm
- $K_m$  = mixing factor to account for poor or random mixing

(Note:  $K_m = 2$  to 5;  $K_m = 2$  is optimum)

$C_a$  = acceptable airborne concentration of the material, typically half of the PEL.

The number of air changes per hour is the number of times one volume of air is replaced in the space per hour. In practice, replacement depends on mixing efficiency. When using dilution ventilation:

- \* position exhausts as close to emission sources as possible,
- \* use auxiliary fans for mixing,
- \* make sure employees are upwind of the dilution zone, and
- \* add make-up air where it will be most effective.

## LOCAL EXHAUST VENTILATION SYSTEMS

A typical local exhaust ventilation system is composed of five parts: fans, hoods, ducts, air cleaners, and stacks.

Local exhaust ventilation is designed to capture an emitted contaminant at or near its source, before the contaminant has a chance to disperse into the workplace air.

### FAN SELECTION

To choose the proper fan for a ventilation system, this information must be known:

- \* air volume to be moved;
- \* fan static pressure;
- \* type and concentration of contaminants in the air as this affects the fans, fan type and materials of construction; and
- \* the importance of noise as a limiting factor.

Once this information is available, the type of fan best suited for the system can be chosen. Many different fans are available, although they all fall into one of two classes:

- \* axial flow fans
- \* centrifugal fans.

For a detailed explanation of fans, see the most recent edition of the ACGIH Industrial Ventilation Manual.

### HOODS

The hood captures, contains, or receives contaminants generated at an emission source. The hood converts duct static pressure to velocity pressure and hood entry losses, e.g., slot and duct entry losses.

Hood entry loss [ $H_e$ ] is:

$$H_e = K \times VP = |SP_h| = VP$$

Where

$K$  = loss factor

$VP$  = velocity pressure in duct

$|SP_h|$  = absolute static pressure about 5 duct diameters down the duct from the hood.

A hood's ability to convert static pressure to velocity pressure is given by the coefficient of energy ( $C_e$ ):

$$C_e = Q_{\text{ideal}}/Q_{\text{actual}} = \sqrt{VP/SP_h} = \sqrt{1/(1+K)}$$

To minimize air-flow requirements, the operation should be enclosed as much as possible, either with a ventilated enclosure, side baffles, or curtains. This helps both to contain the material and to minimize the effect of room air currents. When using a capture or receiving hood, the hood should be located as close to the contaminant source as possible.

Reducing the amount of contaminants generated or released from the process reduces ventilation requirements.

The hood should be designed to achieve good air distribution into the hood openings so that all the air drawn into the hood helps to control contaminants. Avoid designs that require that the velocities through some openings be very high in order to develop the minimum acceptable velocity through other openings or parts of the hood.

The purpose of most ventilation systems is to prevent worker inhalation of contaminants. For this reason, the hood should be located so that contaminants are not drawn through the worker's breathing zone. This is especially important where workers lean over an operation such as an open-surface tank or welding bench.

Hoods must meet the design criteria in the ACGIH Industrial Ventilation Manual or applicable OSHA standards. Most hood design recommendations account for cross-drafts that interfere with hood operation. Strong cross-drafts can easily reduce a hood's effectiveness by 75%. Standard hood designs may not be adequate to contain highly toxic materials.

The hood should be designed to cause minimum interference with the performance of work. Positioning access doors inside an enclosure that must be opened and closed often means that in practice the doors will be left open, and locating capture hoods too close to the process for the worker's convenience often means that the hood will be disassembled and removed.

Hoods should never increase the likelihood of mechanical injury by interfering with a worker's freedom to move around machinery.

Two common misconceptions about hoods that are a part of local exhaust systems are:

- Hoods draw air from a significant distance away from the hood opening, and therefore they can control contaminants released some distance away. It is easy to confuse a fan's ability to blow a jet of air with its ability to draw air into a hood. Hoods must be close to the source of contamination to be effective.
- Heavier-than-air vapors tend to settle to the workroom floor and therefore can be collected by a hood located there. A small amount of contaminant in the air (1000 ppm means 1000 parts of contaminant plus 999,000 parts of air) has a resulting density close to that of air, and random air currents will disperse the material throughout the room.

## **DUCTS**

Air flows turbulently through ducts at between 2000-6000 feet per minute (fpm). Ducts can be made of galvanized metal, fiberglass, plastic, and concrete. Friction losses vary according to ductwork type, length of duct, velocity of air, duct area, density of air, and duct diameter.

## **AIR CLEANERS**

The design of the air cleaner depends on the degree of cleaning required. Regular maintenance of air cleaners increases their efficiency and minimizes worker exposure. Different types of air cleaners are made to remove:

- \* particulates (e.g., precipitators, cyclones, etc.); and
- \* gases and vapors (e.g., scrubbers).

## **STACKS**

Stacks disperse exhaust air into the ambient environment. The amount of re-entrainment depends on exhaust volume, wind speed and direction, temperature, location of intakes and exhausts, etc. When installing stacks:

- \* provide ample stack height, generally a minimum of 10 ft above adjacent rooflines or air intakes;
- \* place stack downwind of air intakes;
- \* provide a stack velocity of a minimum of 1.4 times the wind velocity;
- \* place the stack as far from the intake as possible (50 ft is recommended );
- \* place the stack at least 10 ft high on most roofs to avoid recirculation; and
- \* avoid rain caps if the air intake is within 50 ft of the stack.

## **MAKE-UP AIR SYSTEMS**

Exhaust ventilation systems require the replacement of exhausted air. Replacement air is often called make-up air. Replacement air can be supplied naturally by atmospheric pressure through open doors, windows, wall louvers, and adjacent spaces, as well as through cracks in walls and windows, beneath doors, and through roof vents. Make-up air can also be provided through dedicated replacement air systems. Generally, exhaust systems are interlocked with a dedicated make-up air system.

Other reasons for designing and providing dedicated make-up air systems are that they:

- \* avoid high-velocity drafts through cracks in walls, under doors, and through windows;
- \* avoid differential pressures on doors, exits, and windows; and
- \* provide an opportunity to temper the replacement air.

If make-up air is not provided, a slight negative pressure will be created in the room and air flow through the exhaust system will be reduced.

## **HVAC**

HVAC (heating, ventilating, and air-conditioning) system is a common term that can also include cooling, humidifying or dehumidifying, or otherwise conditioning air for comfort and health. HVAC also is used for odor control and the maintenance of acceptable concentrations of carbon dioxide.

Air-conditioning has come to include any process that modifies the air for a work or living space: heating or cooling, humidity control, and air cleaning. Historically, air-conditioning has been used in industry to improve or protect machinery, products, and processes. The conditioning of air for humans has become normal and expected. Although the initial costs of air conditioning are high, annual costs may account only for about 1% to 5% of total annual operating expenses. Improved human productivity, lower absenteeism, better health, and reduced housekeeping and maintenance almost always make air-conditioning cost effective.

Mechanical air-handling systems can range from simple to complex. All distribute air in a manner designed to meet ventilation, temperature, humidity, and air-quality requirements established by the user.

Individual units may be installed in the space they serve, or central units can serve multiple areas.

HVAC engineers refer to the areas served by an air handling system as zones. The smaller the zone, the greater the likelihood that good control will be achieved; however, equipment and maintenance costs are directly related to the number of zones. Some systems are designed to

provide individual control of rooms in a multiple-zone system.

Both the provision and distribution of make-up air are important to the proper functioning of the system. The correct amount of air should be supplied to the space. Supply registers should be positioned to avoid disruption of emission and exposure controls and to aid dilution efforts.

Considerations in designing an air-handling system include volume flow rate, temperature, humidity, and air quality. Equipment selected must be properly sized and may include:

- \* outdoor air plenums or ducts;
- \* filters;
- \* supply fans and supply air systems;
- \* heating and cooling coils;
- \* humidity control equipment;
- \* supply ducts;
- \* distribution ducts, boxes, plenums, and registers;
- \* dampers;
- \* return air plenums;
- \* exhaust air provisions;
- \* return fans; and
- \* controls and instrumentation.

## RECIRCULATION

Although not generally recommended, recirculation is an alternative to air exchanging. Where used, recirculation should incorporate air cleaners, a by-pass or auxiliary exhaust system, regular maintenance and inspection, and devices to monitor system performance. Key points to consider in the use of recirculation are shown in Table II:3-6.

**TABLE II:3-6. RECIRCULATION CRITERIA**

* Protection of employees must be the primary design consideration.
* The system should remove as much of the contaminant as can economically be separated from exhaust air.
* The system must effectively control employee exposure below the levels specified in T8-CCR.
* The system should not be designed simply to achieve PEL levels of exposure.
* The system should never allow recirculation to significantly increase existing exposures.
* Recirculation should not be used if a carcinogen is present.
* The system should have fail-safe features, e.g., warning devices on critical parts, back-up systems.
* Cleaning and filtering devices that ensure continuous and reliable collection of the contaminant should be used.
* The system should provide a by-pass or auxiliary exhaust system for use during system failure.
* The system should include feedback devices that monitor system performance, e.g., static pressure taps, particulate counters, amperage monitors.
* The system should be designed not to recirculate air during equipment malfunction.
* The employer should train employees in the use and operation of the system.

## **APPENDIX II:3-2. TROUBLESHOOTING AN EXHAUST SYSTEM- SOME HELPFUL HINTS**

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Most of the following checks can be made by visual observation and do not require extensive measurements. Measurements must be taken to verify conditions.

### **IF AIR FLOW IS LOW IN HOODS, CHECK THE FOLLOWING:**

- \* Fan rotation: Reversed polarity will cause fan to run backwards; a backward-running centrifugal fan delivers only 30-50% of rated flow. Fan blades installed upside down. Smoke tubes will assist in determining direction of air flow.
- \* Fan RPM : Slipping belts maybe the cause of ventilation not meeting design criteria.
- \* Fan Restrictions: Clogged or corroded fan wheel and casing
- \* Clogged ductwork: High hood static pressure and low air flow may indicate restricted ducts; open clean-out doors and inspect inside ducts
- \* Closed dampers: Dampers partially or completely closed in ductwork
- \* Clogged dust collectors: Particulate collectors, bags, filters or air cleaning devices may restrict flow.
- \* Weather cap: Weather cap may act as a damper if installed too close to discharge stack: a 3/4 duct-diameter gap should exist between cap and stack; weather caps are not recommended.
- \* System designed: Ductwork system may be poorly designed e.g., short radius elbows, branch entries enter main duct at sharp angles and ductwork diameter too small for the air-flow needed
- \* Lack of make-up air: Lack of adequate supply or make-up air causes high negative pressures that affect propeller fan system output and causes high airflow velocities at doors and windows

**IF AIR FLOW IS SATISFACTORY IN A HOOD BUT CONTAMINANT CONTROL IS POOR, CHECK THE FOLLOWING:**

- \* Cross drafts: Check for turbulence and cross current air flows from process air movements, worker-cooling fans and air-supply systems and open doors and windows
- \* Capture velocity: Determine the point at which capture velocity fails to remove contaminate and determine if the work operation is too far from hood opening
- \* Hood enclosure: Evaluate system to determine if door, baffles, or sides may have been opened or removed
- \* Hood type: Determine if hood design is appropriate for process (canopy hoods are usually inappropriate for the control of toxic airborne materials)

## **APPENDIX II:3-3. T8-CCR AND CONSENSUS STANDARDS**

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### **T8-CCR Standards**

The following is a list of sections in T8-CCR that related to ventilation requirements. Only the main section number is listed although many of the sections may contain numerous subsections that contain ventilation requirements. These sections include regulations related to the control of employee exposure to airborne contaminants, confined space hazards and prevention of fire and explosion hazards

#### **I. Unfired Pressure Vessel Safety Orders**

TITLE 8. §472 Charging LP-Gas Vessels.  
TITLE 8. §476 Location and Installation of Underground Tanks.  
TITLE 8. §477 Installation of Aboveground Storage Tanks.  
TITLE 8. §484 Vaporizer Installation (LP-Gas).  
TITLE 8. §493 Storage or Utilization of LP-Gas Within Buildings.  
TITLE 8. §532 Installation of Aboveground Storage Tanks.  
TITLE 8. §533 Location and Installation of Underground Tanks.  
TITLE 8. §540 LNG Vaporizer Installation.  
TITLE 8. §544 Installation of Fuel Tanks or Cylinders for Motor Vehicles and Industrial Trucks.

#### **II. Compressed Air Safety Orders (Work In Compressed Air)**

TITLE 8. §1230. Temperature, Illumination, Sanitation and Ventilation.

#### **III. Construction Safety Orders**

TITLE 8. §1528 General (Engineering Controls).  
TITLE 8. §1529 Asbestos.  
TITLE 8. §1530. General Requirements of Mechanical Ventilation Systems.  
TITLE 8. §1532 Cadmium.  
TITLE 8. §1532.1. Lead.  
TITLE 8. §1533 Internal Combustion Engines.  
TITLE 8. §1535 Methylenedianiline.  
TITLE 8. §1536. Ventilation Requirements for Welding, Brazing, and Cutting.  
TITLE 8. §1541 General Requirements (Excavations).  
TITLE 8. §1562 Construction and Use of First-Class Magazines.  
TITLE 8. §1693 Temporary Heating Devices.  
TITLE 8. §1706. LP-Gas Fired Space Heaters.  
TITLE 8. §1728 Handling Coal Tar Pitch.  
TITLE 8. §1743 General Precautions (Oxygen, Acetylene & Fuel Gas).  
TITLE 8. §1931 Inside Storage (Flammable & Combustible Liquids).  
TITLE 8. §1934 Dispensing Liquids.

TITLE 8. §1938 Construction Site, General (Code of Safe Practices)

#### **IV. Electrical Safety Orders**

.  
TITLE 8. §2540.1 Scope (Hazardous Locations).  
TITLE 8. §2540.5 Commercial Garages, Repair and Storage.  
TITLE 8. §2540.8 Bulk-Storage Plants.  
TITLE 8. §2540.9 Finishing Processes.  
TITLE 8. §2540.10 Wastewater Wells.  
TITLE 8. §2548.21 General (Oil & Gas Wells).  
TITLE 8. §2548.25 Wiring Methods (Oil & Gas Wells)..  
TITLE 8. §2565.2. Supply Circuits and Interconnecting Cables (Data Processing).  
TITLE 8. §2805 Vaults - General.  
TITLE 8. §2806 Vaults Containing Oil-Filled Equipment.  
TITLE 8. §2874 General ( Transformers).  
TITLE 8. §2920. Ventilation System Controls (Mine and Tunnel).  
TITLE 8. §2925 General (Hazardous Locations).

#### **V. Elevator Safety Orders**

TITLE 8. §3011 Machine Rooms and Machinery Spaces.  
TITLE 8. §3034 Car Enclosures and Car Doors and Gates.

#### **VI. General Industry Safety Orders**

TITLE 8. §3222. Arrangement and Distance to Exits.  
TITLE 8. §3287 Ladders (Storage Areas).  
TITLE 8. §3305 Misuse of Oxygen Prohibited.  
TITLE 8. §3309 Drainage and Ventilation.  
TITLE 8. §3406 Body Protection.  
TITLE 8. §3462 Hazardous Cargo.  
TITLE 8. §3663 Maintenance of Industrial Trucks.  
TITLE 8. §4307 Portable Power Driven Circular Hand Saws.  
TITLE 8. §4415 Stock Preparation and Reprocessing (Pulp, Paper & Paperboard Mills).  
TITLE 8. §4421 Recovery Furnace Area (Pulp, Paper & Paperboard Mills).  
TITLE 8. §4807 Ventilation, Lighting and Heating of Generator Houses or Rooms.  
TITLE 8. §4825 Installation-General (Service Piping for All Gases).  
TITLE 8. §4853 Inert-Gas Metal-Arc Welding.  
TITLE 8. §5140. Definitions (Control of Hazardous Substances).  
TITLE 8. §5142. Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC)  
Systems  
TITLE 8. §5143. General Requirements of Mechanical Ventilation Systems.  
TITLE 8. §5146 Internal Combustion Engine Exhaust Emission Control.  
TITLE 8. §5150. Ventilation & PPE Requirements for Welding, Brazing and Cutting.  
TITLE 8. §5151.(a) Ventilation & PPE Requirements for Abrasive Blasting Operations.

TITLE 8. §5152. Ventilation & PPE Requirements for Grinding, Polishing, and Buffing Operations.

TITLE 8. §5153. Ventilation & PPE Requirements for Spray Coating Operations.

TITLE 8. §5154. Ventilation & PPE Requirements for Open-Surface Tank Operations.

TITLE 8. §5154.1 Ventilation Requirements for Laboratory-Type Hood Operations.

TITLE 8. §5154.2 Ventilation Requirements for Biological Safety Cabinets.

TITLE 8. §5157 Permit-Required Confined Spaces.

TITLE 8. §5158 Other Confined Space Operations.

TITLE 8. §5168 Static Electricity.

TITLE 8. §5188 Molten Salt Baths.

TITLE 8. §5189 Process Safety Management of Acutely Hazardous Materials.

TITLE 8. §5190 Cotton Dust.

TITLE 8. §5191 Occupational Exposure to Hazardous Chemicals in Laboratories.

TITLE 8. §5193 Biological Bloodborne Pathogens.

TITLE 8. §5200.5. Methylenedianiline.

TITLE 8. §5207 Cadmium.

TITLE 8. §5208 Asbestos.

TITLE 8. §5208.1 Non Asbestiform Tremolite, Anthophyllite, and Actinolite.

TITLE 8. §5209 Carcinogens.

TITLE 8. §5212 1,2 Dibromo-3-Chloropropane (DBCP).

TITLE 8. §5213. Acrylonitrile.

TITLE 8. §5214 Inorganic Arsenic.

TITLE 8. §5215 4,4 ' -Methylenebis(2-Chloroaniline).

TITLE 8. §5216 Lead.

TITLE 8. §5217 Formaldehyde.

TITLE 8. §5218 Benzene.

TITLE 8. §5220 Ethylene Oxide.

TITLE 8. §5223 Fumigation in Buildings or Rooms Other Than Fumigation Vaults or Chambers.

TITLE 8. §5228 Labels (Various Label Statements).

TITLE 8. §5244 Explosives for Underground Use.

TITLE 8. §5254 First-Class Magazines.

TITLE 8. §5361.(b) Structures (Ammonium Nitrate Storage).

TITLE 8. §5363.(b) Bulk Storage (Ammonium Nitrate Storage).

TITLE 8. §5415. Definitions (Flammable Liquids, Gases & Vapors).

TITLE 8. §5416 Flammable Vapors.

TITLE 8. §5417 Flammable Liquids-General.

TITLE 8. §5418 Carboys and Drums Containing Flammable Liquids.

TITLE 8. §5427 Ventilation (Dip Tanks).

TITLE 8. §5429 Conveyor Systems (Dip Tanks).

TITLE 8. §5433 Operations and Maintenance (Dip Tanks).

TITLE 8. §5438 Electrostatic Apparatus (Dip Tanks).

TITLE 8. §5449.(m) Electrical and Other Sources of Ignition (Spray Coating).

TITLE 8. §5450. Ventilation (Spray Coating).

TITLE 8. §5455 Electrostatic Hand Spraying Equipment (Spray Coating).

TITLE 8. §5456 Drying, Curing or Fusion Apparatus (Spray Coating).

TITLE 8. §5459 Automobile Undercoating in Garages (Spray Coating).  
TITLE 8. §5460 Powder Coating (Spray Coating).  
TITLE 8. §5473 Specific Requirements (Hydrogen).  
TITLE 8. §5475 Separate Buildings (Hydrogen).  
TITLE 8. §5476 Special Rooms (Hydrogen).  
TITLE 8. §5493 Handling Liquefied Hydrogen Inside Buildings  
TITLE 8. §5495 Separate Buildings (Hydrogen).  
TITLE 8. §5496 Special Rooms (Hydrogen).  
TITLE 8. §5502 Distance Between Bulk Oxygen Systems and Exposures.  
TITLE 8. §5530 Scope (Electrical Equipment).  
TITLE 8. §5534 Design & Construction of Inside Storage Rooms (Container/Portable Tanks).  
TITLE 8. §5545 General (Industrial Plants).  
TITLE 8. §5546 General (Industrial Plants Flammable & Combustible Liquids).  
TITLE 8. §5556 Construction (Processing Plants Flammable & Combustible Liquids).  
TITLE 8. §5566 Storage (Service Stations Flammable & Combustible Liquids).  
TITLE 8. §5571 Fuel Dispensing System (Service Stations Flammable & Combustible Liquids).  
TITLE 8. §5574 Electrical Equipment (Service Stations Flammable & Combustible Liquids).  
TITLE 8. §5589 Installation of Outside Aboveground Tanks.  
TITLE 8. §5618 Ventilation (Bulk Plants Flammable & Combustible Liquids).  
TITLE 8. §6057 Equipment Procedures and Requirements (Diving Operations).

## **VII. Petroleum Safety Orders-Drilling And Production**

TITLE 8. §6529 Confined Space Ventilation ( Reference to GISO).

## **VIII. Petroleum Safety Orders-Refining, Transportation And Handling**

TITLE 8. §6775 Static Electricity.  
TITLE 8. §6793 Confined Space Ventilation (Reference to GISO).

## **IX. Mine Safety Orders**

TITLE 8. §6958 Definitions.  
TITLE 8. §7057 Mine Exit Protection.  
TITLE 8. §7058 Fire Doors and Fire Bulkheads.  
TITLE 8. §7064 Combustible Liquids and Gases - Surface Storage.  
TITLE 8. §7070 Permit to Use Diesel Engines Underground.  
TITLE 8. §7076 Fire and Safety Diagram.  
TITLE 8. §7083 Mine Rescue Stations.  
TITLE 8. §7084 Mine Rescue Equipment and Supplies.  
TITLE 8. §7086 Use of Mine Rescue Equipment.  
TITLE 8. §7096 Dust, Smoke, and Gases from Secondary Blasting.  
TITLE 8. §7098 Ventilation.  
TITLE 8. §7099 Mechanical Ventilation.  
TITLE 8. §7206 Explosives for Underground Use.

TITLE 8. §7213 First-Class Magazines.  
TITLE 8. §7262.(f) Buildings (Mixing Blasting Agents)

#### **X. Ship Building, Ship Repairing & Ship Breaking Safety Orders**

TITLE 8. §8355 Confined and Enclosed Spaces and Other Dangerous Atmospheres.  
TITLE 8. §8357 Inert-Gas Shielded Metal-Arc Welding.  
TITLE 8. §8384 Tools and Equipment.

#### **XI. Tunnel Safety Orders**

TITLE 8. §8422.(3) Tunnel Classifications.  
TITLE 8. §8422. Tunnel Classifications.  
TITLE 8. §8424.(d) Dangerous or Poisonous Gases.  
TITLE 8. §8425.(d) Operation of Gassy and Extrahazardous Tunnels.  
TITLE 8. §8425.(g) Operation of Gassy and Extrahazardous Tunnels.  
TITLE 8. §8426.(d) Emergency Plan.  
TITLE 8. §8437 Ventilation (Air Quality T8-CCR 5155).  
TITLE 8. §8458 Dust Control.  
TITLE 8. §8470 Fuel-Burning Internal Combustion Engines.  
TITLE 8. §8510 Explosives for Underground Use.  
TITLE 8. §8517 First-Class Magazines.  
TITLE 8. §8537 Loading Explosives - General.  
TITLE 8. §8568. Blaster's License Fees.

#### **XII. Telecommunication Safety Orders**

TITLE 8. §8609 Other Tools and Personal Protective Equipment.  
TITLE 8. §8616. Underground Lines.

## INDUSTRY CONSENSUS STANDARDS

Standard	Source	Title
<b>AIR FILTERS</b>		
ASHRAE 52-76	ASHRAE	Methods of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
<b>EXHAUST SYSTEMS</b>		
ANSI Z33.1-1982	NFPA	Installation of Blower and Exhaust Systems for Dust,
NFPA 91-1983	NFPA	Stock, Vapor Removal or Conveying (1983)
ANSI Z9.2-1979	AIHA	Fundamentals Governing the Design and Operation of Local Exhaust Systems
ANSI Z9.1-1977	AIHA	Practices for Ventilation and Operation of
	ASHRAE	Open-Surface Tanks
ANSI Z9.3-1964	ANSI	Safety Code for Design, Construction, and Ventilation of Spray Finishing Operations (reaffirmed 1971)
ANSI Z9.4-1979	ANSI	Ventilation and Safe Practices of Abrasives Blasting
ANSI Z9.4A-1981		Operations
ANSI Z9.5-1992	AIHA	Laboratory Ventilation
<b>FANS</b>		
AMCA 99-83	AMCA	Standards Handbook Electric Fans (1977)
ANSI/UL 507-1976	UL	
ASHRAE 51-75	ASHRAE	Laboratory Methods of Testing Fans for Rating
AMCA 210-74		
ANSI/ASHRAE 87.1-1983	ASHRAE	Methods of Testing Dynamic Characteristics of Propeller Fans--Aerodynamically Excited Fan Vibrations and Critical Speeds

AMCA 210-74	AMCA	Laboratory Methods of Testing Fans for Rating Purposes
AMCA 99-2404-78	AMCA	Drive Arrangement for Centrifugal Fans
AMCA 99-2406-83	AMCA	Designation for Rotation and Discharge of Centrifugal Fans
AMCA 99-2407-66	AMCA	Motor Positions for Belt or Chain Drive Centrifugal Fans
AMCA 99-2410-82	AMCA	Drive Arrangement for Tubular Centrifugal Fans

## **INDUSTRIAL DUCT**

SMACNA	SMACNA	Round Industrial Duct Construction
SMACNA	SMACNA	Rectangular Industrial Duct Construction

## **VENTING**

NFPA 68	NFPA	Guide for Explosion Venting
NFPA 204M	NFPA	Guide for Smoke and Heat Venting
SMACNA	SMACNA	Guide for Steel Stack Design and Construction (1983)

## **VENTILATION**

NFPA 96	NFPA	Vapor Removal from Cooking Equipment (1984)
NFPA-88A, 88B	NFPA	Parking Structures (1979); Repair Garages (1979)
ASHRAE 62-1989	ASHRAE	Ventilation for Acceptable Indoor Air Quality
ACGIH	ACGIH	Industrial Ventilation

## **SOURCES OF CONSENSUS STANDARDS**

Copies of the consensus standards are published and available directly from the organization issuing the standard. A minimal fee is often required.

Source	Organization
ACGIH	American Conference of Governmental Industrial Hygienists 6500 Glenway Ave., Bldg. D-5 Cincinnati OH 45211
AIHA	American Industrial Hygiene Association 2700 Prosperity Ave., Suite 250 Fairfax VA 22031-4319

AMCA	Air Movement and Control Association 30 W. University Dr. Arlington Heights IL 60004
ANSI	American National Standards Institute 1430 Broadway New York, NY 10018
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329
NFPA	National Fire Protection Association Batterymarch Park Quincy, MA 02269
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association 8224 Old Courthouse Rd. Vienna, VA 22180
UL	Underwriters Laboratories Inc. 333 Pfingsten Rd., Northbrook, IL 60062

## **APPENDIX II:3-4. GLOSSARY**

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**ACFM.** Actual cubic feet per minute of gas flowing at existing temperature and pressure. (See also SCFM.)

**AIR CHANGES PER HOUR (ACH, AC/H).** The number of times air is replaced in an hour.

**AIR DENSITY.** The weight of air in lbs per cubic foot. Dry standard air at  $T = 68^{\circ}\text{F}$  ( $20^{\circ}\text{C}$ ) and  $\text{BP} = 29.92$  in Hg (760 mm Hg) has a density of 0.075 lb/cu ft.

**ANEMOMETER.** A device that measures the velocity of air. Common types include the swinging vane and the hot-wire anemometer.

**AREA (A).** The cross-sectional area through which air moves. Area may refer to the cross-sectional area of a duct, a window, a door, or any space through which air moves.

**ATMOSPHERIC PRESSURE.** The pressure exerted in all directions by the atmosphere. At sea level, mean atmospheric pressure is 29.92 in Hg, 14.7 psi, 407 in w.g., or 760 mm Hg.

**BRAKE HORSEPOWER (bhp).** The actual horsepower required to move air through a ventilation system against a fixed total pressure plus the losses in the fan.  $\text{bhp} = \text{ahp} \times 1/\text{eff}$ , where eff is fan mechanical efficiency.

**BRANCH.** In a junction of two ducts, the branch is the duct with the lowest volume flow rate. The branch usually enters the main at an angle of less than 90 degrees.

**CANOPY HOOD (Receiving Hood).** A one-or two-sided overhead hood that receives rising hot air or gas.

**CAPTURE VELOCITY.** The velocity of air feet per minute induced by a hood to capture emitted contaminants external to the hood.

**COEFFICIENT OF ENTRY  $C_e$ .** A measure of the efficiency of a hood's ability to convert static pressure to velocity pressure; the ratio of actual flow to ideal flow.

**DENSITY CORRECTION FACTOR.** A factor applied to correct or convert dry air density of any temperature to velocity pressure; the ratio of actual flow to ideal flow.

**DILUTION VENTILATION (General Exhaust Ventilation).** A form of exposure control that involves providing enough air in the workplace to dilute the concentration of airborne contaminants to acceptable levels.

**ENTRY LOSS.** See Hood Entry Loss or Branch Entry Loss.

**EVASE.** A cone-shaped exhaust stack that recaptures static pressure from velocity pressure

(pronounced eh-va-say) .

**FAN.** A mechanical device that moves air and creates static pressure.

**FAN LAWS.** Relationships that describe theoretical, mutual performance changes in pressure, flow rate, rpm of the fan, horsepower, density of air, fan size, and sound power.

**FAN CURVE.** A curve relating pressure and volume flow rate of a given fan at a fixed fan speed (rpm).

**FRICTION LOSS.** The static pressure loss in a system caused by friction between moving air and the duct wall, expressed as in w.g./100 ft, or fractions of VP per 100 ft of duct (mm w.g./m; Kpa/m).

**GAUGE PRESSURE.** The difference between two absolute pressures, one of which is usually atmospheric pressure.

**GENERAL EXHAUST VENTILATION.** See Dilution Ventilation.

**HEAD.** Pressure; e.g., "The head is 1 in water gauge i.e., w.g."

**HOOD.** A device that encloses, captures, or receives emitted contaminants.

**HOOD ENTRY LOSS  $H_e$ .** The static pressure lost in inches of water when air enters a duct through a hood with the majority of the loss usually associated with a vena contracta formed in the duct.

**HOOD STATIC PRESSURE  $SP_h$ .** The sum of the duct velocity pressure and the hood entry loss; hood static pressure is the static pressure required to accelerate air at rest outside the hood into the duct at velocity.

**HVAC (HEATING, VENTILATION, AND AIR CONDITIONING) SYSTEMS.** Ventilating systems designed primarily to control temperature, humidity, odors, and air quality.

**INDOOR AIR QUALITY (IAQ), SICK-BUILDING SYNDROME, TIGHT-BUILDING SYNDROME.** The study, examination, and control of air quality related to temperature, humidity, and airborne contaminants.

**IN, INCHES OF WATER (w.g.).** A unit of pressure with one inch of water equal to 0.0735 in of mercury, or 0.036 psi. Atmospheric pressure at standard conditions is 407 in w.g.

**INDUSTRIAL VENTILATION (IV).** The equipment or operation associated with the supply or exhaust of air by natural or mechanical means to control occupational hazards in the industrial setting.

**LAMINAR FLOW (also Streamline Flow).** Air flow in which air molecules travel parallel to all other molecules; laminar flow is characterized by the absence of turbulence.

**LOCAL EXHAUST VENTILATION.** An industrial ventilation system that captures and removes emitted contaminants before dilution into the ambient air of the workplace.

**LOSS.** Usually refers to the conversion of static pressure to heat in components of the ventilation system, e.g., "the hood entry loss."

**MAKE-UP AIR.** See Replacement and Compensating Air.

**MANOMETER.** A device that measures pressure difference; usually a U-shaped glass tube containing water or mercury.

**MINIMUM TRANSPORT VELOCITY (MTV).** The minimum velocity that will transport particles in a duct with little settling; MTV varies with air density, particulate loading, and other factors.

**OUTDOOR AIR (OA).** Outdoor air is the "fresh" air mixed with return air (RA) to dilute contaminants in the supply air.

**PITOT TUBE.** A device used to measure total and static pressures in an airstream.

**PLENUM.** A low-velocity chamber used to distribute static pressure throughout its interior.

**PRESSURE DROP.** The loss of static pressure across a point; for example, "the pressure drop across an orifice is 2.0 in w.g."

**REPLACEMENT AIR (also, Compensating Air, Make-Up Air).** Air supplied to a space to replace exhausted air.

**RETURN AIR.** Air that is returned from the primary space to the fan for recirculation.

**SCFM.** (See Standard Cubic Feet Per Minute)

**STANDARD CUBIC FEET PER MINUTE (scfm).** A measure of air flow at standard conditions, i.e., dry air at 29.92 in Hg (760 mm Hg) (gauge), 68°F (20°C).

**SLOT VELOCITY.** The average velocity of air through a slot. Slot velocity is calculated by dividing the total volume flow rate by the slot area (usually,  $V_s = 2,000$  fpm).

**STACK.** A device on the end of a ventilation system that disperses exhaust contaminants for dilution by the atmosphere.

**STANDARD AIR, STANDARD CONDITIONS.** Dry air at 68°F (20°C), 29.92 in Hg (760

mm Hg).

**STATIC PRESSURE (SP).** The pressure developed in a duct by a fan; the force in inches of water measured perpendicular to flow at the wall of the duct; the difference in pressure between atmospheric pressure and the absolute pressure inside a duct, cleaner, or other equipment; SP exerts influence in all directions.

**SUCTION PRESSURE.** (See **Static Pressure**.) An archaic term that refers to static pressure on the upstream side of the fan.

**T8-CCR.** Title 8, California Code of Regulations.

**TOTAL PRESSURE (TP).** The pressure exerted in a duct, i.e., the sum of the static pressure and the velocity pressure; also called Impact Pressure, Dynamic Pressure.

**TRANSPORT VELOCITY.** See Minimum Transport Velocity.

**TURBULENT FLOW.** Air flow characterized by transverse velocity components as well as velocity in the primary direction of flow in a duct; mixing velocities.

**VELOCITY (V).** The time rate of movement of air; usually expressed as feet per minute.

**VELOCITY PRESSURE (VP).** The pressure attributed to the velocity of air.

**VOLUME FLOW RATE (Q).** Quantity of air flow in cfm, scfm, or acfm.